Perspective

Pursuing the Goal

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NREL's focus on science and technology, from innovation to implementation, is to make abundant energy available to all people with minimal adverse effects on our environment. This 2003 edition of the NREL *Research Review* highlights some of the technology development advances we have made toward that goal, beginning with the production of hydrogen from renewable sources. NREL scientists made important strides in methods including the gasification and pyrolysis of biomass, electrolysis of water using electricity produced by wind and other renewable energy technologies, and direct water-splitting via photoelectrochemical and photobiological techniques. (See "New Horizons for Hydrogen," page 2.)

In biomass research, NREL worked with industry to engineer enzymes that are more efficient at breaking down cellulose into sugars, culminating in a 12-fold reduction in the cost of enzymes. (See "Unraveling the Structure of Plant Life," page 10.) Researchers also determined how to increase the amount of solids that could be tolerated in slurries while producing sugars from biomass, which will markedly reduce the cost of bio-based fuels, chemicals, and other products.

NREL took another step forward in 2003 toward the goal of cheaper, more reliable wind power by developing a capability to test industry's wind turbine blades at their natural resonant frequency along two axes of the blade. This enables researchers to assess a wide range of larger blades for their tendency toward fatigue and delamination. As one of the most rapidly growing renewable electricity technologies, wind energy is a critical technology in offsetting carbon dioxide emissions that contribute to global warming. (See "Winds of Change," page 16.)

Photovoltaics is also a vital technology that will reduce carbon dioxide emissions from conventional electricity production. NREL researchers and their industry partners recently set five conversion efficiency records, one involving the world's most efficient cell design — a triple-junction $GaInP_2/GaAs/Ge$ cell that converts 36.9% of solar energy to electricity under a concentration of 309 suns. As another example, thin-film cells have reached efficiencies of 19.2%, a performance similar to standard multicrystalline silicon cells. These lab-scale advances will ultimately help lower the cost of commercial-scale solar modules.

In the area of advanced vehicle and fuel technologies to reduce our dependence on foreign oil, NREL has licensed its simulation software — ADVISOR — to AVL Group, a company that develops power trains and advanced vehicle simulation technologies. ADVISOR is a modeling tool that helps automakers design fuel cell and hybrid power trains for optimum vehicle performance, economy, and emissions; and already has an established user community of several thousand users.

In buildings energy research, NREL scientists developed software — BE*opt* — that enables engineers, architects, and others to choose the best materials and designs to minimize building energy use and costs for any given climate and location. The software also shows the most effective and least costly path toward designing buildings that could achieve zero net energy use.

NREL is in the forefront of the developments needed to bring distributed generation of electricity into the marketplace, which will benefit not only individual buildings but also industrial plants, communities, and other localized electrical loads. Working with industry and utilities, NREL researchers led the effort to develop and win approval for new uniform national standards for the interconnection of distributed generation technologies. These standards will enable the interconnection of distributed generation systems of various types to the electrical grid, other distributed systems, and individual loads, helping to improve power reliability and quality while improving the environment.

The foundation of all this work is our basic understanding of the materials and fundamental mechanisms related to these technologies. In 2003, nanosciences made important advances at NREL. Scientists are using self-assembling proteins — bacterial cellulosomes — to organize III-V semiconductor quantum dots into arrays, with eventual applications in high-efficiency solar cells, solid-state lighting, and lasers. NREL also made significant progress in understanding and developing carbon nanotube structures that can store effective amounts of hydrogen in a lightweight device for future use in fuel-cell vehicles.

Computational science is becoming an equal partner with experimental and theoretical science (see page 24). NREL scientists are simulating the diffusion of oxygen and hydrogen in algal hydrogenase, which will guide genetic modification of the algae and optimize production of hydrogen. Researchers are also simulating the fluid and thermal dynamics of spray cooling to study the application of this technique to automotive electronics, condensers at geothermal power plants, and other areas. With research applications multiplying rapidly, we will continue to build our capability in this critical methodology.

As exciting as these advances have been in 2003, much remains to be done. We look forward to both steady progress and important breakthroughs as we keep pursuing the goal in 2004.